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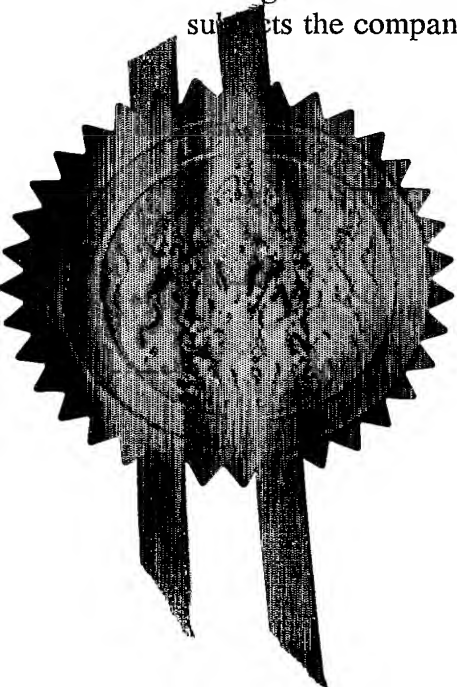
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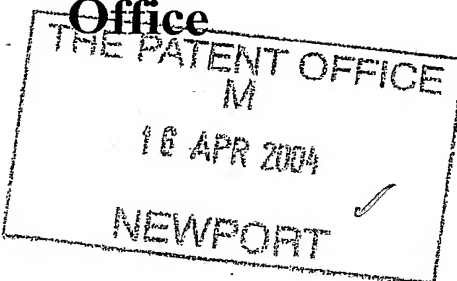
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THE NETHERLANDS
07419294001 ✓

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4. Title of the invention LIQUID-BASED OPTICAL DEVICE AND ELECTRONIC
DEVICE

5. Name of your agent (*if you have one*)

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Description

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Claims(s)

2

Abstract

1

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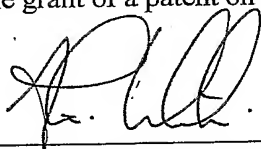
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DESCRIPTION

LIQUID-BASED OPTICAL DEVICE AND ELECTRONIC DEVICE

5

The present invention relates to an optical device comprising a container enclosing an insulating liquid and a conductive liquid, the insulating liquid and the conductive liquid being immiscible and being in contact with each other via an interface, the liquids being placed in a light path through the container; an electrode arrangement for controlling the shape of the interface by means of a voltage.

10

The present invention further relates to an electronic device comprising such an optical device.

15

Optical devices based on the manipulation of liquids are rapidly gaining large commercial interest, not in the least because of their lack of mechanically moving parts and the relative simplicity of the devices, which makes the devices cheap and durable.

20

For instance, in US patent application US2001/0017985 an optical device is disclosed that incorporates two immiscible liquids with equal refractive indices but different transmittances, with one of the two liquids being conductive. By varying the interface between these two liquids, the amount of each of the liquids in the light path through the device is changed and a diaphragm is obtained as a result.

25

International patent application WO03/069380 discloses a cylindrical variable focus lens incorporating two immiscible fluids having different refractive indices, one of the fluids being conductive and the other being insulating. The shape of the interface between the two fluids is manipulated by applying a voltage across the lens, which can be used to introduce a change in the focal point of the lens. The walls of the cylinder and one of the transparent lids of the cylinder are coated with a hydrophobic coating to ensure that at least in a switched off state the conductive fluid, which typically is a polar

30

liquid, does not contact said walls in order to maintain a well-defined interface between the fluids.

A problem that can occur with such devices is that after a period of active use an unintended deformation of the interface can occur, which
5 disturbs the desired optical behaviour of the interface.

The invention seeks to provide an optical device in which the unintended deformation of the interface is avoided.

The invention further seeks to provide an electronic device comprising
10 such an improved optical device.

According to an aspect of the invention, there is provided an optical device comprising a container enclosing an insulating liquid and a conductive liquid, the insulating liquid and the conductive liquid being immiscible and being in contact with each other via an interface, at least one of the liquids
15 being at least partially placed in a light path through the container; an electrode arrangement for controlling the shape of the interface by means of a voltage; and means for preventing a build-up of an electrostatic charge on a surface of the container.

The invention is based on the realization that the unintended
20 deformation of the interface is caused by a build-up of an electrostatic charge on a surface of the container. Such a build-up may for instance be caused by the exposure of the container to external electrical fields or by intentional or unintentional rubbing of the surface of the container.

In an embodiment, the surface is a part of a transparent end portion of
25 the container, the means for preventing a build-up of an electrostatic charge on a surface of the container comprise a conductive layer, the conductive layer forming a part of the transparent end portion. This has the advantage that the accumulation of electrostatic charge on the transparent end portion can be avoided.

30 Advantageously, the electrode arrangement comprises an electrode in contact with the conductive liquid, the conductive layer being conductively coupled to said electrode. In this embodiment, the conductive layer is kept at

the same potential as the conductive liquid, thus ensuring that the presence of any electrostatic charge on the transparent end portion has no influence on the shape of the interface.

5 In a further embodiment, the means for preventing a build-up of an electrostatic charge on a surface of the container comprise a Faraday cage surrounding the container. This embodiment, which may be combined with the previous embodiment, protects the optical device from exposure to external electrical fields, and consequently prohibits the build-up of electrostatic charge on a surface of its container.

10 The Faraday cage may comprise a conductive coating at least partially covering a further container. This has the advantage that the Faraday cage can be produced separately from the optical device.

15 The further container may be at least partially transparent. This has the advantage that the further container can completely encapsulate the container of the optical device, without the optical path through the latter being compromised.

20 According to a further aspect of the invention, there is provided an electronic device including an optical device comprising a container enclosing an insulating liquid and a conductive liquid, the insulating liquid and the conductive liquid being immiscible and being in contact with each other via an interface, at least one of the liquids being at least partially placed in a light path through the container; an electrode arrangement for controlling the shape of the interface by means of a voltage; and means for preventing a build-up of an electrostatic charge on a surface of the container; the electronic device further
25 comprising driver circuitry coupled to the electrode arrangement and a power supply for powering the driver circuitry, the means for preventing a build-up of an electrostatic charge on a surface of the container being coupled to a terminal of the power supply.

30 The electronic device of the present invention has the advantage that the performance of its optical device is not hampered by the accumulation of electrostatic charges on a surface of the container of the optical device.

In an embodiment, the means for preventing a build-up of an electrostatic charge on a surface of the container are coupled to a terminal of the power supply, preferably ground, to ensure that said means are kept on a same potential as the conductive liquid.

5 In an alternative embodiment, the means for preventing a build-up of an electrostatic charge on a surface of the container form a part of an arrangement for shielding an electronic circuit of the electronic device from external radiation. This has the advantage that the optical device can be protected from the build-up of electrostatic charge by extending an
10 arrangement already present in the electronic device, which is cost-effective.

The invention is described in more detail and by way of non-limiting examples with reference to the accompanying drawings, wherein:

15 Fig. 1 schematically depicts a prior art variable focus lens;

Fig. 2 schematically depicts an optical device according to the present invention;

Fig. 3 schematically depicts another optical device according to the present invention;

20 Fig. 4 schematically depicts an electronic device according to the present invention; and

Fig. 5 schematically depicts another electronic device according to the present invention.

25 It should be understood that the Figures are merely schematic and are not drawn to scale. It should also be understood that the same reference numerals are used throughout the Figures to indicate the same or similar parts.

In Fig. 1, a variable focus lens as disclosed in International Patent
30 application WO 03/069380 is shown. The variable focus lens comprises a first fluid A and a second fluid B housed in a cylindrical chamber. The fluids are immiscible, have different refractive indices and preferably have the same

density to avoid orientation-dependent gravitational effects on the orientation of the fluids including the interface 14 between the fluids. The cylindrical chamber further comprises a first end portion 4 and a second end portion 6, with the first end portion 4 as well as the inner walls of the cylindrical chamber being covered by a hydrophobic coating such as AF1600TM from the DuPont company, which may be combined with a stack of parylene, to confine the conductive fluid B by the insulating fluid A in the absence of an applied voltage. The shape of the interface 14 can be switched in a continuous fashion from a convex shape shown in orientation (a) to a concave shape shown in orientation (b) by varying a voltage from a value V1 to a value V2 across the cylindrical electrode 2 embedded in the chamber wall and a, preferably transparent, annular electrode 12 on the second lid 6 which is in conductive contact with the second fluid B. Consequently, the focal point of the light path L through the cylinder is altered.

The transparent end portion 4 may be a glass or polymer lid or another suitable transparent material, which may be lens-shaped. The exposure of the container of the fluids A and B to an external electrical field or the rubbing of the transparent end portion 4, e.g., cleaning the end portion with a cloth or accidental rubbing of the end portion 4 by wearing the optical device in a pocket of a garment, can cause the accumulation of an electrostatic charge on a surface of the container such as the transparent end portion 4. This charge can attract the conductive fluid B, thereby disturbing the shape of the interface 14 between the fluids A and B, as shown in (c), thus causing a deviation of the desired optical behaviour of the lens. Since it can take several hours or longer for the electrostatic charge to leak away, it will be obvious that this is a highly unwanted effect.

It is emphasized that although this undesirable effect is explained using the prior art lens from International Patent application WO 03/069380 as an example, other liquid-based optical devices such as the diaphragm disclosed in US patent application US2001/0017985 can equally suffer from this problem.

In Fig. 2 and the following figures, the variable focus lens of Fig. 1 will be shown as an embodiment of the optical device of the present invention. It is emphasized, however, that the teachings of the present invention also apply to other liquid-based optical devices. In Fig. 2, the variable focus lens of Fig. 1 is extended with a conductive layer 100 for preventing a build-up of an electrostatic charge on a surface of the container of the lens, i.e., on the first end portion 4. The conductive layer 100 is shown on the inner surface of the end portion 4, but an orientation on the outer surface of the end portion 4 is also feasible. The conductive layer 100 can be realized with any known transparent conductive material such as indium tin oxide (ITO), Indium trioxide (In_2O_3) or tin dioxide (SnO_2). Preferably, the conductive layer 100 is kept at the same potential as the conductive liquid B, which can be realized by conductively coupling the conductive layer 100 to the electrode 12 in contact with the conductive liquid B, as shown in Fig. 2. Alternatively, the conductive layer 100 may be conductively coupled to a current sink, such as ground.

Fig. 3 shows another embodiment of an optical device of the present invention. The variable focus lens of Fig. 1 is placed inside a further container 120. The further container 120 may be open opposite the end portion 4 and the end portion 6 of the variable focus lens, or may have transparent sections opposite those end portions. The further container 120 may further comprise a metal body, or may further comprise a non-conductive material such as plastic or glass, which may be transparent. In case of the further container 120 comprising such a non-conductive material, the further container 120 further comprises a conductive coating 140, which may be transparent, and which may reside on an inner surface or an outer surface of the further container 120.

Consequently, the further container 120 acts as a Faraday cage around the variable focus lens, thus preventing a build-up of an electrostatic charge on a surface of the container. The conductive coating 140 may also be applied to the outer surface of the container of the variable focus lens, in which case the further container 120 can be omitted. Preferably, the conductive coating 140 or a conductive further container 120 are conductively coupled to the conductive

liquid B to ensure that the Faraday cage is kept at the same potential as the conductive liquid B. This conductive coupling may be realized via the electrode 12. It is emphasized that the aforementioned embodiments of a Faraday cage may be combined with any of the embodiments of the conductive layer 100 as shown in Fig. 2 without departing from the scope of the present invention.

Fig. 4 shows an embodiment of an electronic device 1 of the present invention, including an optical device having a conductive layer 100 on the end portion 4, as shown in Fig. 2 and its detailed description. The electronic device 1 further includes driver circuitry 20 for applying a voltage across the electrode arrangement including electrodes 2 and 12, and an image sensor 30 for capturing an image that enters the electronic device 1 via the light path of the optical device. The driver circuitry 20 and the image sensor 30 are powered by a power supply 40, which has one of its terminals, e.g., ground, coupled to the conductive layer 100. This may also be the ground of the electronic device 1. Alternatively, the conductive layer 100 may also be coupled to the power supply 40 via the electrode 12, in an arrangement analogous to that shown in Fig. 2.

Fig. 5 shows another embodiment of an electronic device 1 of the present invention, including a liquid-based optical device, e.g., a variable focus lens, driver circuitry 20, an image sensor 30 and a power supply (not shown). The electronic device 1 further comprises an electronic circuit 50, which is shielded from external radiation, i.e., radiation from outside the electronic circuit, by shielding material 60. The shielding material 60 may be any suitable material known to the skilled person, e.g., a conductive foil or a metal housing. The shielding material 60 is extended over the container of the optical device without blocking the light path through the optical device to prevent a build-up of an electrostatic charge on a surface of the container of the optical device.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. The word

"comprising" does not exclude the presence of elements or steps other than those listed in a claim. The word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. The invention can be implemented by means of hardware comprising several distinct elements. In
5 the device claim enumerating several means, several of these means can be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

CLAIMS

1. An optical device comprising:
 - 5 a container enclosing an insulating liquid (A) and a conductive liquid (B), the insulating liquid (A) and the conductive liquid (B) being immiscible and being in contact with each other via an interface (14), at least one of the liquids (A; B) being at least partially placed in a light path through the container;
 - an electrode arrangement (2; 12) for controlling the shape of the
 - 10 interface (14) by means of a voltage; and
 - means (100, 120, 140) for preventing a build-up of an electrostatic charge on a surface of the container.
2. An optical device as claimed in claim 1, wherein the surface is a part of
15 a transparent end portion (4) of the container; the means for preventing a build-up of an electrostatic charge on a surface of the container comprise a conductive layer (100), the conductive layer (100) forming a part of the transparent end portion (4).
- 20 3. An optical device as claimed in claim 2, wherein the electrode arrangement (2; 12) comprises an electrode (12) in contact with the conductive liquid (B), the conductive layer (100) being conductively coupled to said electrode (12).
- 25 4. An optical device as claimed in claim 1 or 2, wherein the means for preventing a build-up of an electrostatic charge on a surface of the container comprise a Faraday cage (120, 140) surrounding the container.
5. An optical device as claimed in claim 4, wherein the Faraday cage
30 comprises a conductive coating (140) at least partially covering further container (120).

6. An optical device as claimed in claim 5, wherein the further container (120) is at least partially transparent.

7. An electronic device (1) including an optical device comprising:

5 a container enclosing an insulating liquid (A) and a conductive liquid (B), the insulating liquid (A) and the conductive liquid (B) being immiscible and being in contact with each other via an interface (14), at least one of the liquids (A; B) being at least partially placed in a light path through the container;

an electrode arrangement (2; 12) for controlling the shape of the
10 interface (14) by means of a voltage; and

means (60, 100) for preventing a build-up of an electrostatic charge on a surface of the container;

driver circuitry (20) coupled to the electrode arrangement (2; 12); and
a power supply (30) for powering the driver circuitry (20).

15

8. An electronic device (1) as claimed in claim 7, wherein the means (100) for preventing a build-up of an electrostatic charge on a surface of the container are coupled to a terminal of the power supply (30).

20 9. An electronic device (1) as claimed in claim 7, wherein said terminal is the ground.

10. An electronic device (1) as claimed in claim 7 or 8, wherein the means for preventing a build-up of an electrostatic charge on a surface of the
25 container form a part of an arrangement (60) for shielding an electronic circuit (50) of the electronic device (1) from external radiation.

ABSTRACT

LIQUID-BASED OPTICAL DEVICE AND ELECTRONIC DEVICE

- 5 The present invention discloses an optical device comprising a container enclosing an insulating liquid (A) and a conductive liquid (B), the insulating liquid (A) and the conductive liquid (B) being immiscible and being in contact with each other via an interface (14), at least one of the liquids (A; B) being at least partially placed in a light path through the container. The optical device
- 10 further comprises an electrode arrangement (2; 12) for controlling the shape of the interface (14) by means of a voltage; and means (100) for preventing a build-up of an electrostatic charge on a surface of the container. Consequently, the build-up of electrostatic charge on a surface of the optical device is avoided, which prevents the unwanted distortion of the interface (14)
- 15 caused by the interaction of the conductive liquid (B) and the electrostatic charge.

Fig. 2



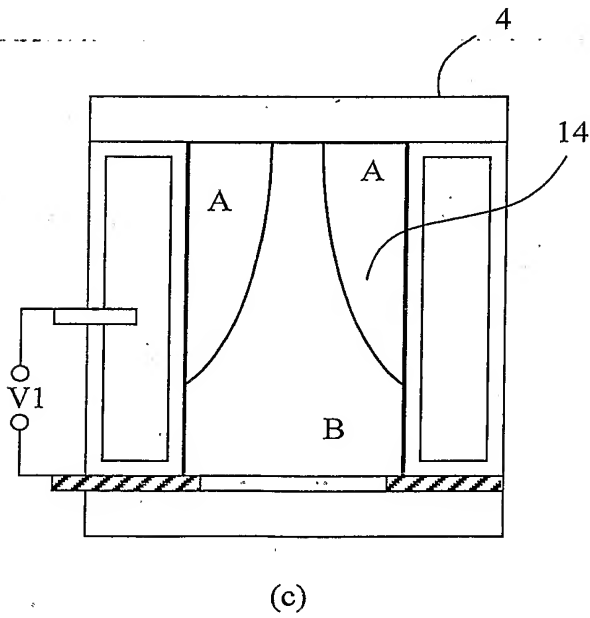
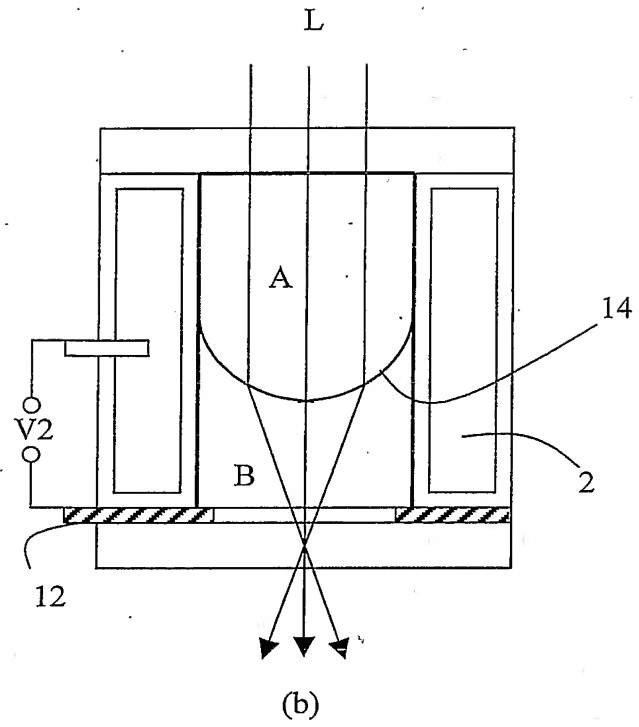
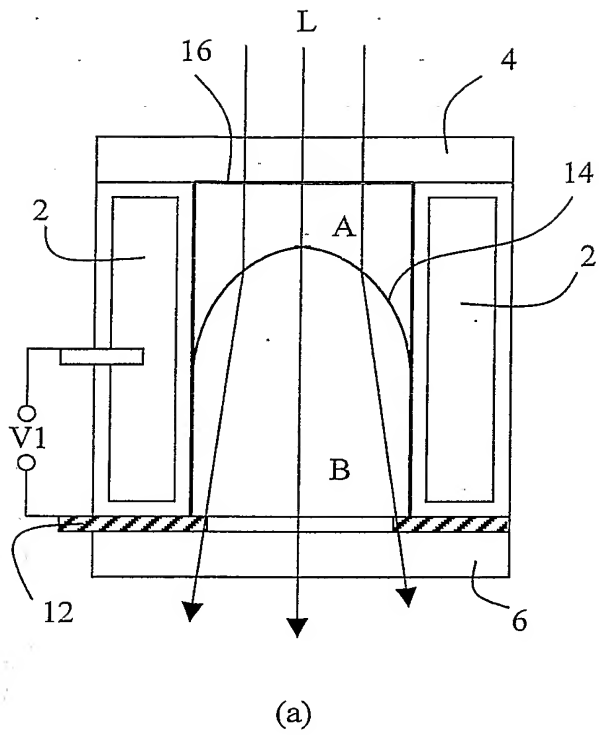


Fig. 1 (prior art)



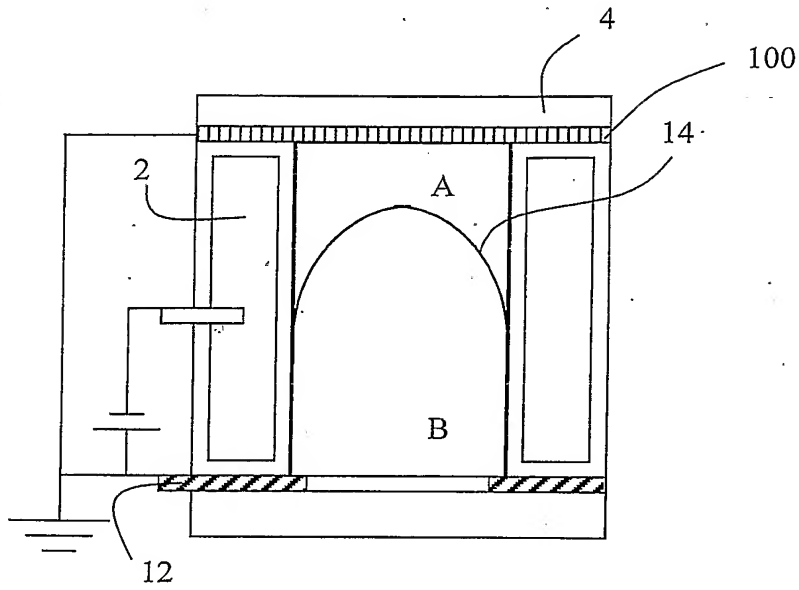


Fig. 2

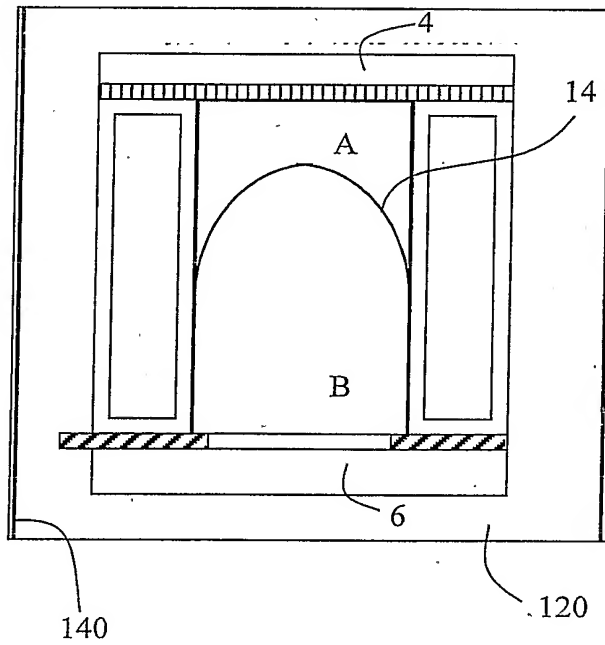


Fig. 3



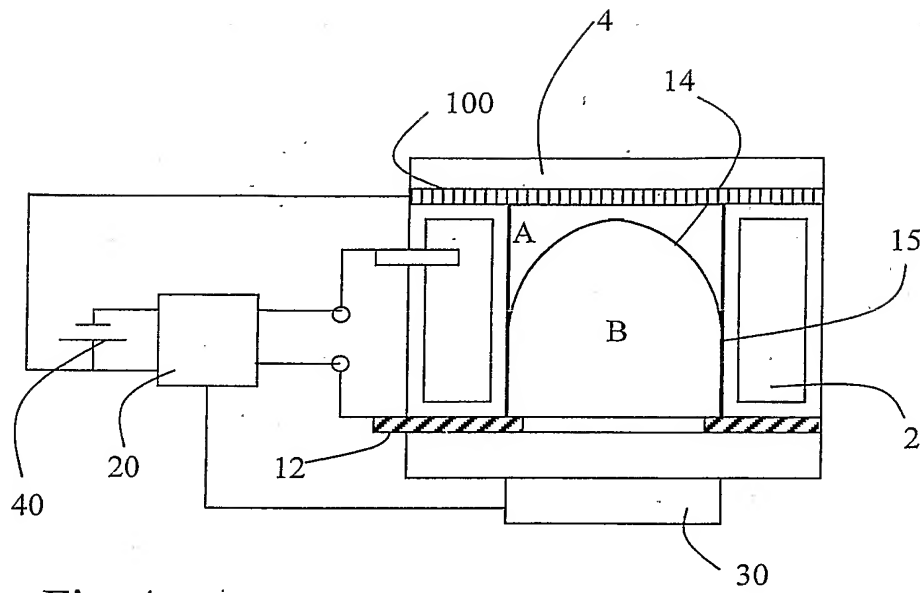


Fig. 4

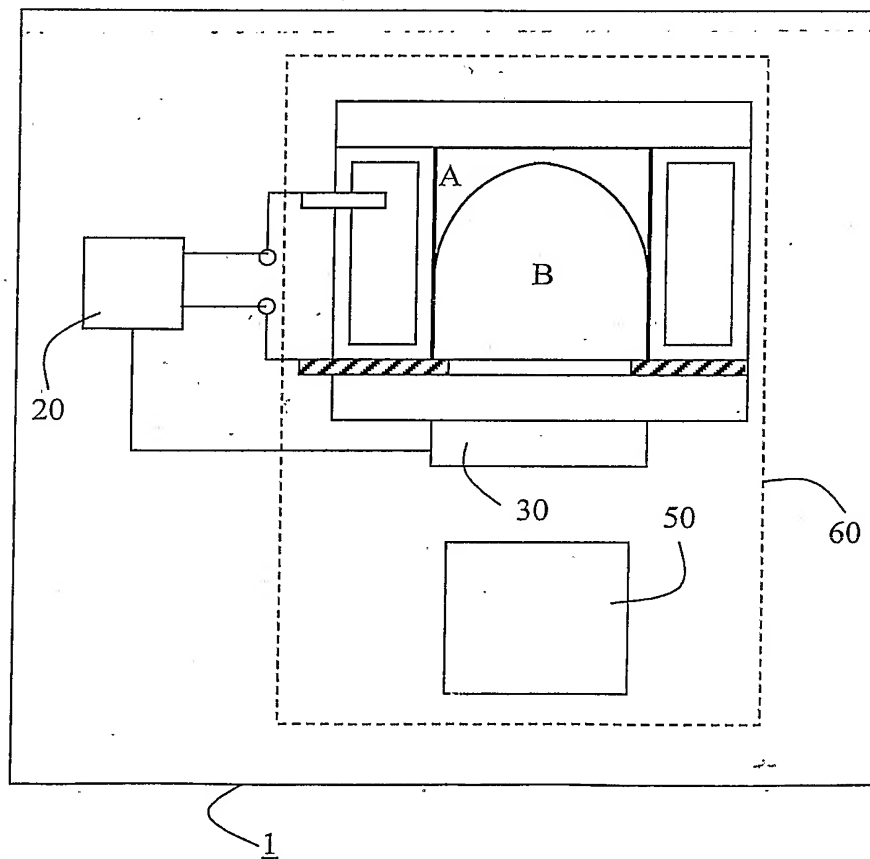


Fig. 5

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